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CHANNEL INCISION AT EAGLEHAWK CREEK, GIPPSLAND, VICTORIA, AUSTRALIA

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Abstract: A hundred years ago, when the land around Glengarry was subdivided into small farms, Eaglehawk Creek was a shallow shifting watercourse interspersed with patches of swamplands. Efforts to drain the land and contain the creek have led to incision, creating a channel up to 15 m deep. The progress of incision can be documented from historical evidence including the personal recollection of residents of the area. Phases of rapid deepening associated with major floods have alternated with periods of stability recorded as terraces in the channel sides. The present phase of relatively slow erosion probably reflects the absence of high flows in the last three years rather than the attainment of a stable grade.

Many of the river channels in Gippsland, in eastern Victoria have undergone extensive geomorphological change since the area was settled by Europeans 150 years ago. Among the most striking examples of change is the channel incision which has occurred along the northern tributaries of the Latrobe River. This paper describes the history of that erosion with particular reference to Eaglehawk and Stoney Creeks (Fig. 1), and discusses the factors that have led to the conversion of the shifting surface streams of the pre-agricultural landscape into the gullies up to 15 m deep which are seen in the area today (Fig. 2).

In the United States there have been many studies of channel changes in the post settlement period: while most researchers have concluded that human interference has been the main cause, a few, such as Bull (1964) have suggested that in some cases climatic events, such as periods of exceptionally heavy rainfall, may have been significant. Cooke and Reeve (1976) reviewed the extensive literature on arroyos, deep gullies which are widespread in the western USA. They concluded from their own studies in Arizona and California that arroyos resulted from floristic change, particularly that associated with livestock grazing, and destruction of valley floor vegetation with a consequent increase in the susceptibility of channels to erosion. Malde and Scott (1977), in a study of contemporary arroyo development near Santa Fe in New Mexico, analysed the processes of gullying but emphasised the problem of isolating any single cause, because the onset of erosion in the 1880s coincided with several other changes, including a transition from grassland to scrub vegetation, and a general lowering of water tables in the area. In the mid-west of the United States channel erosion is also prevalent. Daniels (1960) presented a case study of Willow County Ditch in Iowa, which has entrenched several metres into its former floodplain since the beginning of the century; he considered that while regional modification of run off may have been a contributory factor, the most important cause was an increase in stream gradient resulting from channel straightening.

In Europe eroding channels are less common, but an example is the Devon gully described by Gregory and Park (1976) which was believed to be due to modification of run off caused by urbanisation. Incision of channels in a forested area in Luxembourg was also ascribed to change in surface run off, in this case the result of concentration along culvert underpasses and drainage ditches (Imeson & Jungerius 1977).

Recognition of the impact of settlement on river channels in Australia came early, and the remarks of John Robertson (1853, quoted in Bride 1898) concerning the development of gullying in the Western District of Victoria are often quoted. Abbott (1884, p. 105) was more specific when he described changes in run-off in inland New South Wales: "The difference between stocked country and that which has never been stocked is apparent even after a few years. The surface becomes firmer and water runs where it never ran before . . it does not now take half the amount of rain to put water in the rivers that it did thirty years ago, just after it was first settled."

More recently Woodyer (1968) emphasised the dominance of incised channel forms in New South Wales; he quoted Dury as saying that these had developed in the 200 years since European settlement. Pickup (1975) analysed the process of incision along Crawfords Creek, near Picton, where instability was initiated by a severe flood in 1949. In a later paper Pickup (1976) described a regional prevalence of incision with particular reference to the Cumberland Basin, but here analysis of precipitation records, which extend back as far as 1880, suggested a recent increase in rainfall with consequent growth in the magnitude and frequency of flooding as the most likely cause.

Goede (1972), in a study of Tea Tree Rivulet in northeastern Tasmania, emphasised the role of vegetation clearing, particularly alongside the gullied sector, in promoting channel instability, which was probably also influenced by a trend towards an increased number of small rain falls since about 1917. In South Australia channel deepening over the past century was described

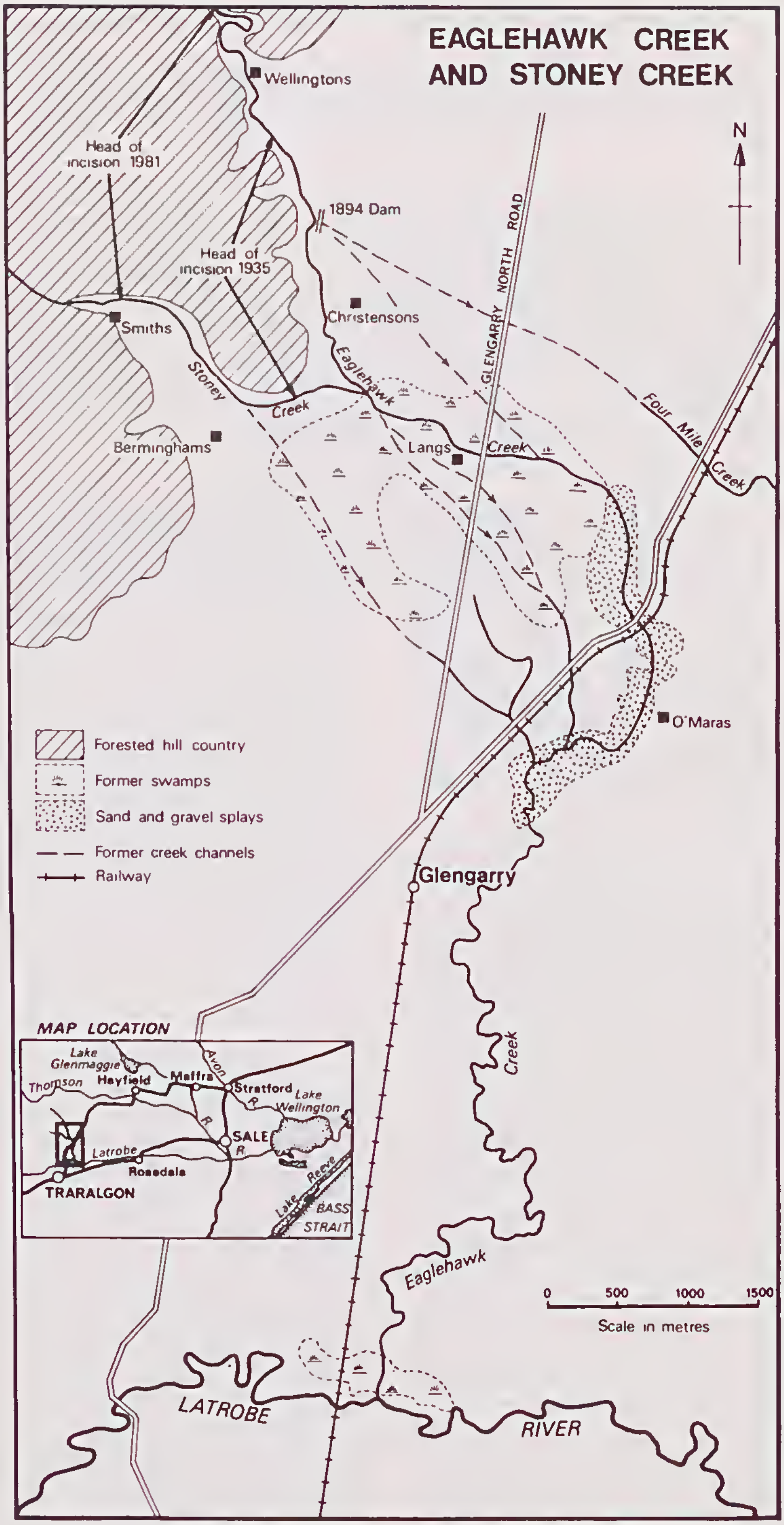

Fig. 1 – Study area on Eaglehawk and Stoney Creeks.

Fig. 2—Eaglehawk Creek 200 m downstream from Christensons, looking downstream. Figure arrowed for scale.

by Bourmann (1976) who attributed it to increased runoff following deforestation and ploughing. Bourmann also cited specific cases of erosion developing along channels dug to drain swamplands.

In Victoria Bird (1980) concluded that incision along the Lang Lang River had several causes, which she was unable to rank in order of importance. In the lower part of the valley, swamps had been drained and the river course had been straightened, which resulted in lowered base levels and increased channel gradient. Upstream sectors had also been straightened, while construction of a levee bank blocked a depression which formerly permitted egress of flood waters from the Lang Lang channel onto swamplands to the north.

Eaglehawk and Stoney Creeks are particularly favourable for a study of geomorphological change. Air photographs are available for 1935, 1964, 1970 and 1976. A railway line, built in 1883, crosses Eaglehawk Creek just below the main incised sector and maintenance surveys made by the Victorian Railway Authority record erosion and sediment deposition at the bridge site at frequent intervals. Most of the changes have occurred within the last seventy years, so that farmers in the area today recall them either personally, or through stories related by their parents, many of whom were the original settlers who opened up the land for agriculture. While personal memory is often an unreliable source of evidence, it is likely to be accurate where events, such as destruction of important access tracks, seriously affect farm management.

THE LOCAL SETTING

Eaglehawk and Stoney Creeks rise in Palaeozoic hill country, at an altitude of about 380 m and in the upper part of their courses they flow through dissected terrain covered with open eucalypt forest which has been extensively logged. Part of the area has been cleared and replanted with conifers for a nearby paper mill. On leaving the forest the streams cross a foothill zone formed by coalescing fans with surface gradients of 0.010. Under natural conditions the fans enclosed swampy tracts (Fig. 1), where stream courses became indistinct before re-emerging as defined channels to cross the terraces of the Latrobe. Eaglehawk Creek flows directly into the Latrobe River, unlike the other watercourses in this region, which terminate in the back-swamps at the edge of the flood plain.

The foothill zone was originally occupied by squatters in the 1840s but little vegetation clearing occurred until after the land was resumed for release under the Selection Acts of the 1860s. Small farmers were then encouraged to settle in the area to grow food for the miners who passed through on their way to the Walhalla goldfields, but the swampy terrain proved unsuitable for cropping, and there was little progress until the construction of the railway in 1883. After that improved transport ensured rapid development, mainly of dairy farming to supply local butter factories, and by the 1930s most of the forest had been cleared and replaced with improved pasture.

THE DEVELOPMENT OF EROSION

The shifting stream courses (Fig. 1) (The information on flow routes and vegetation derives from the land selection files of the 1860s, many of which include plans of the individual subdivisions.) were a nuisance to the local farmers, and in 1894 they tried to control Eaglehawk Creek by constructing a dam to block the flood overflow which formerly travelled across a low col into the catchment of Four Mile Creek. About the same time, the farmer who owned the land west of the Glengarry North Road enlarged one of the channels taking Eaglehawk Creek across his property with the dual aim of eliminating the changes of course and draining the swamps. The local Shire Council (Rosedale) then extended this channel east of the road, directing the water into the depression leading to the northernmost of the three bridges which carried the railway across branches of Eaglehawk Creek. Present stream alignment still follows this northern route, though subsequent erosion and meandering have eliminated the signs of its man-made origin.

The first record that Eaglehawk Creek was changing dates from 1910, when engineers noted instability beneath the railway bridge; nine years later the bridge had to be partially rebuilt following a flood which widened the underlying waterway. Thereafter it was sediment deposition rather than erosion which caused bridge maintenance problems. Incision becomes evident about 1 km above the railway, though in this lower part the incised channel is partially infilled with sediment. Evidence for the early development of erosion is sparse, but in 1914 Eaglehawk Creek was still small enough to be crossed by a minor footbridge at Christensons, while each winter floods caused problems when they overflowed down the access track to the local school. By 1920 there was a large waterfall 300 m above Langs, and in 1929 the channel just above the Glengarry North Road was said to be very deep. (Mrs Timmins pers. comm.). The 1935 air photographs show active incision extending to about 500 m below Wellingtons, and ground photographs taken at this time indicate that the channel was already 10 m deep above the junction with Stoney Creek. By 1939 the Forest (now Frasers) Road crossing at Wellingtons was threatened, and ten years later erosion at this point was described as severe. Above the bridge, bedrock outcropping in the channel slowed the progress of erosion, but where the valley is infilled incision is still evident 1 km upstream.

Under natural conditions Stoney Creek, like Eaglehawk, lacked a defined channel across the fan zone and was prone to change its course. At the time of settlement it flowed on an alignment similar to the present one as far as the site of Bermingham's Farm, then became dispersed in a swamp before reforming into a channel just above the railway. According to a local farmer (Jack Lang pers. comm.) his father, in 1932 or 1933, had been impressed with the effectiveness of the eroding Eaglehawk channel for swamp drainage and the rapid removal of floodwater from the hills so he decided to direct Stoney Creek into it by way of a ditch around the base of the spur dividing the two catchments. Incision spread rapidly back up the ditch into the old channel with the head of the erosion already 500 m above the confluence by 1935. By the early 1940s incision extended back to Berminghams, where it repeatedly cut the access track to the hills: attempts to maintain a bridge at this point (Fig. 3) were finally abandoned about 1952. (Date from Raymond Smith, son of the owner of a property upstream from this point, who depended on this bridge for access.) Figure 4 includes a cross section of the channel at the bridge site today. Like Eaglehawk, Stoney Creek has now cut down to bedrock in several places, and although further upstream extension of incision is likely, it will be a much slower process than in the lower course.

An average figure for the rate of upstream transmission of the head of gullying can be deduced from the historical evidence. Over the period 1920-1935 it moved from the vicinity of the Glengarry North road bridge to above Christensons, a distance of 2 km, a rate of about 133 m a year. Between 1935 and 1939, when erosion is recorded at Wellingtons, the head of the incision migrated a further 500 m, indicating a similar annual rate. In Stoney Creek movement in the first 3 years was very rapid — 500 m — but it subsequently slowed to a rate comparable to that in Eaglehawk Creek.

Average figures for headward extension though useful for comparison with gully development elsewhere, are somewhat misleading, because it is clear that incision has been an episodic process, with periods of rapid development in high flows interspersed with years of near stability when no major floods occurred. Valley side benches in the channel of Eaglehawk Creek between Stoney Creek and Wellingtons are relics of former channel floor levels temporarily stabilised behind weirs. In the early years incision appears to have been accomplished through the headward migration of prominent knickpoints, which may have originated on harder bands within the fan sediments, or behind weirs which became breached. About 1952 the headwall which had marked the upstream limit of incision became degraded into a series of rapids and though a few steps persist behind intact drop structures, or associated with rocky sectors or blocking logs, none are more than 40-60 cm high. Even the upper limit of incision is ill defined, as above Frasers Road stable rocky sectors alternate with patches of infill where the former valley floor is preserved as a terrace 1-2 m above the present channel floor. The contrast between the present smooth profile, and the irregular one described in early records may be due to diminution of downcutting due to the attainment of a stable grade, or may reflect a change in the nature of the sediment load. In the early years incision in the lower part of the fan released a load dominated by silt, sand and gravel; as erosion has extended back into the hills it has cut into increasingly coarse material so that it is likely that a greater proportion of the sediment now moves as bedload. Goede (1972) suggested that the absence of a prominent headwall in an eroding gully may be attributed to a preponderance of coarse material

A

B

Fig. 3—A, Bridge across Stoney Creek at Berminghams, looking upstream. About 1936. (Source: R. Smith, Glengarry). B. Same site in August 1944. Remains of the old bridge in the foreground. (Source: State Rivers and Water Supply Commission photograph collection).

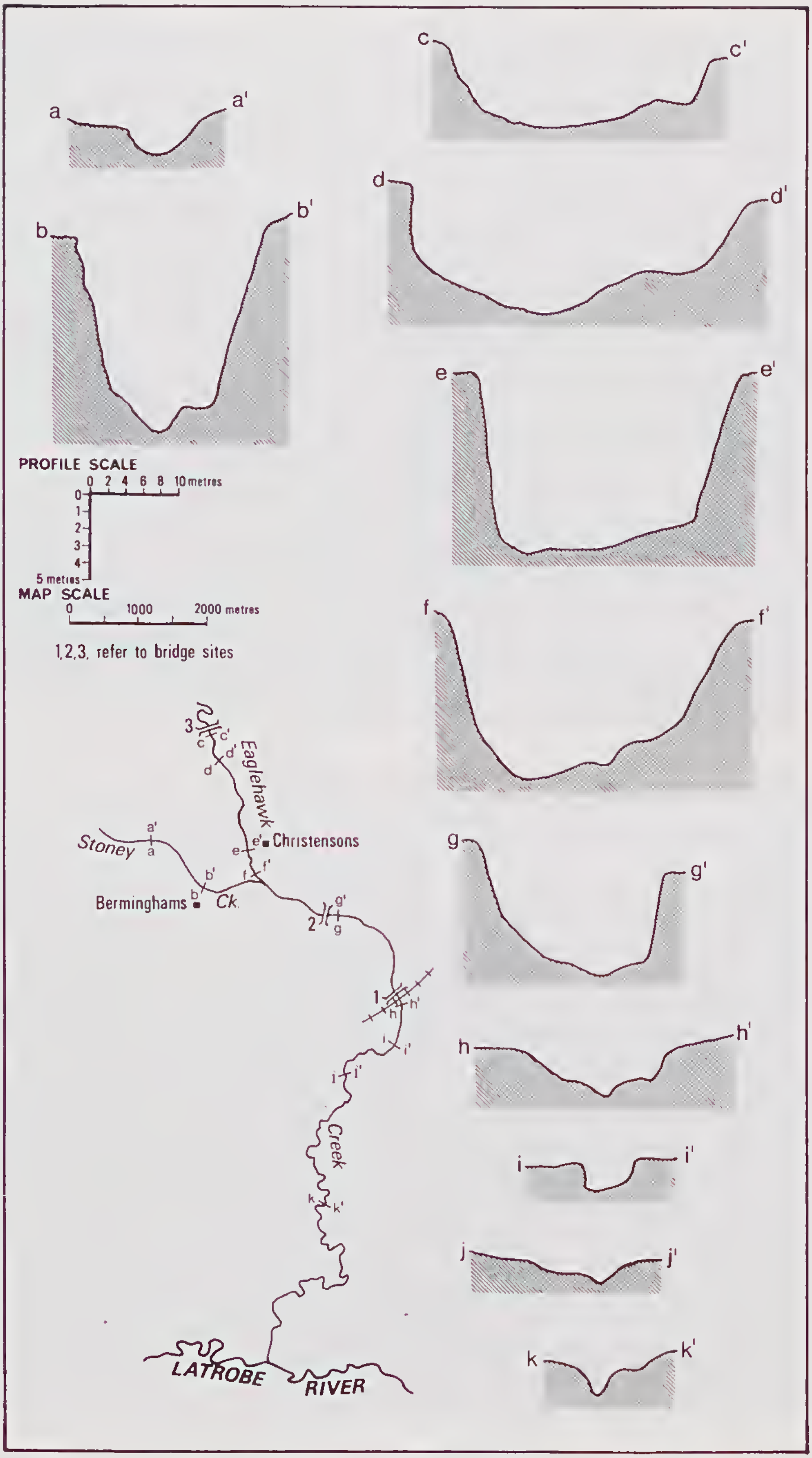

Fig. 4 — Cross-sections of Eaglehawk and Stoney Creeks at the positions indicated.

in the sediment load. The change in sediment size may also be reflected in the the changing shape of the cross profile. Historical data suggest that deepening was dominant in the early years, so that sections attained a depth of 10 m or more by 1935; since that time the maximum depth has only increased to around 15 m, but the rate of sediment delivery downstream, together with the visible signs of bank undercutting, show that widening, particularly on bends, is still active. Schumm (1977) has demonstrated that channel width-depth ratios are related to sediment size, and the transition from dominant down-cutting to dominant widening may be associated with the increasing proportion of bed load in transit. This may also explain the lower width-depth ratios noted in Stoney Creek, which is deeper and narrower (Fig. 4) and carries finer debris.

SEDIMENT DEPOSITION

Erosion along Eaglehawk and Stoney Creeks has mobilised an estimated 750 000 m^3 of sediment ranging in size from cobbles 6 cm or more in diameter down to fine sand and silt. While the former remain on the bed of the higher reaches, and much of the silt has been carried as suspended load through to the Latrobe River, redeposition of the sand and gravel components of the load has created many problems. Where the creek bed has deepened most of this material has been retained on the channel floor, forming a deep, porous infill, so that surface water flow is much less common than it used to be, thereby reducing the value of the stream as a source of stock water. The area within which this has occurred is shown as a slight convexity on the long profile. The most damaging effect of sediment deposition has been the blocking of the waterway beneath the rail and main-road bridges. The original 1881 railway survey and a profile of the bridge site drawn in 1919 both show a clearance of nearly 3 m between river bed and bridge deck. By 1933 this waterway had been almost obliterated by deposition within the channel and early in 1934 floods banked up behind the bridge to flood 10 hectares of land, leaving 1.5 m of sediment in places. Later that year a flood of even greater magnitude swept the channel clear, transporting sediment further downstream and restoring the waterway profile of 15 years earlier. The improvement was shortlived, and by 1935 railway authorities were forced to excavate material from beneath the bridge to re-establish the channel and prevent the creek from flooding over the line and disrupting train services. For a time it looked as if Eaglehawk Creek might abandon this course altogether and revert to one of its old routes to the south. The railway authorities were unconcerned; they already had bridges that would cope with such a change because when the line was constructed the creek still sometimes flowed in this direction. It was seen as more of a threat by the Shire Council and the Country Roads Board, which maintained the road. The road, built after the railway, had made no provision for an alternative waterway, so that a course diversion would necessitate the construction of a new bridge.

The deposition of sediment across farmland in the region known locally as the "delta" has been detrimental to those farmers directly affected, as the value of pasturelands is reduced when they are blanketed by several centimetres of coarse sand and gravel. The cumulative effect of sediment deposition has been to raise land levels by 2 or 3 m in places, burying fence posts and tree trunks.

ATTEMPTS TO CONTROL EROSION AND SEDIMENTATION

In the 1930s attempts to deal with problems resulting from the erosion of Eaglehawk and Stoney Creeks were confined to periodic excavation of the waterway beneath the main-road and rail bridges, but it became increasingly evident that the problem of infilling could only be solved by the insertion of sediment traps and erosion controls upstream. At first attempts to do this were on a very small scale consisting mainly of brushwood weirs across the channel floor. None of the structures lasted more than a few months before they were washed out by floods, and though the Rosedale Shire Council had consultations with the Soil Conservation Board and the State Rivers and Water Supply Commission in 1942 over a proposal for construction of a major dam across Eaglehawk Creek, no further action was taken for some years. In 1949 the Country Roads Board replaced the old main-road bridge with a new one having a 2 m clearance above the river bed; the following year the Railways, too, replaced their bridge with a new, higher level structure on what was considered an improved alignment. Floods in 1952 washed out the approach to the new road bridge (Fig. 5) and went over the raised rail bridge, but problems at the bridge sites have subequently diminished.

In 1950, following the failure of the early attempts to check erosion and sedimentation, local farmers met to form the Eaglehawk Creek Control League; in 1953 this was taken over by the Latrobe River Improvement Trust when its area of jurisdiction was extended to include Eaglehawk Creek. In 1956 the Trust, in conjunction with the State Rivers and Water Supply Commission, constructed extensive new erosion control works, consisting of about 45 stone and wire-mesh weirs, placed at intervals along Eaglehawk and Stoney Creeks, but within a few months of completion more than two-thirds had been rendered useless because the river outflanked them by undercutting the soft bank sediments. The broken weirs then made the situation worse, because they trapped tree trunks and branches which fell into the river as the forested bank eroded, forcing the creek to migrate around them. By 1957 Eaglehawk Creek just upstream from the confluence with Stoney Creek occupied a vertical sided slot 13 m deep and 30 m wide. For a decade attempts to control erosion were abandoned because it was clear that only a large dam and sediment trap would be effective, and its cost was more than was justified now that the new road and rail bridges had been constructed overcoming the problem of severing the major transport link through the area.

In 1968 a further attempt to control erosion

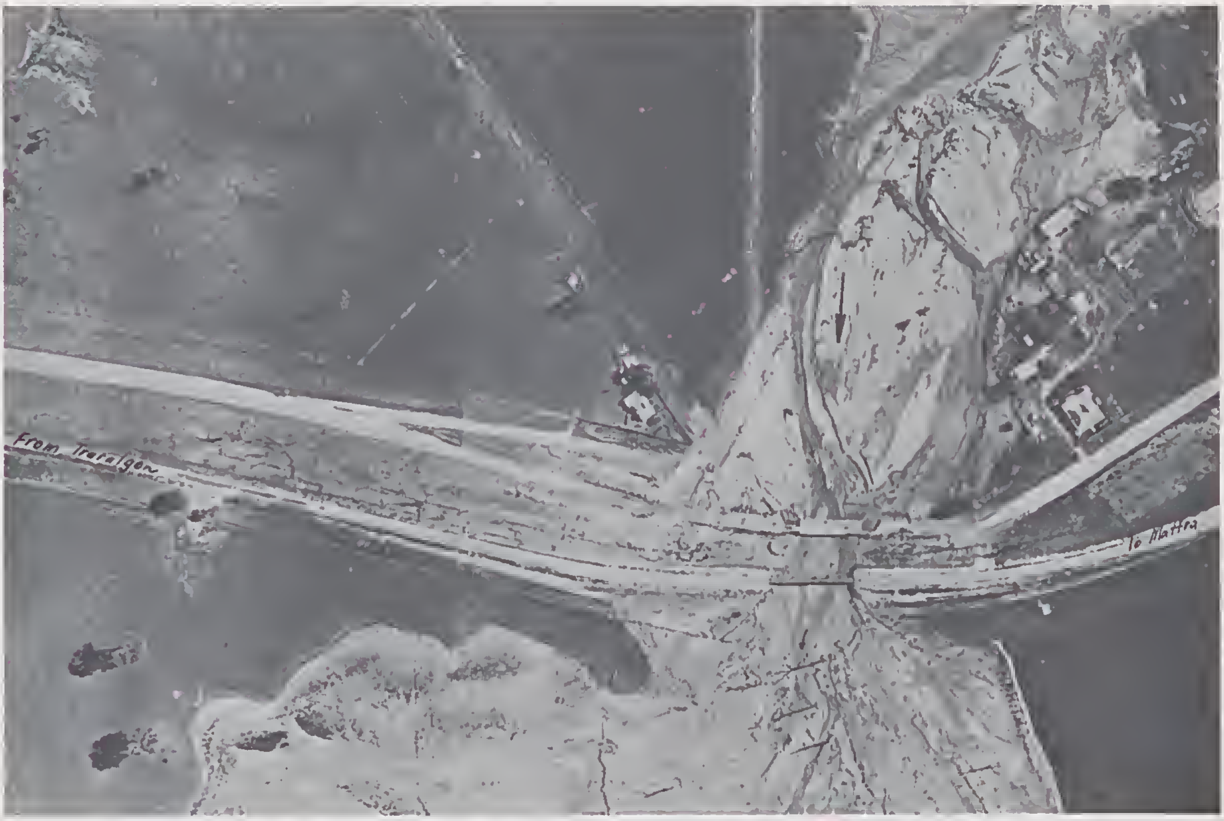

Fig. 5—Aerial photograph of the main road and rail bridges taken just after the 1952 floods, showing sand splays. (Source: Victorian Railways).

through insertion of concrete drop structures was made using Drought Relief Funds to provide local employment, but a flash flood of January 1971 caused severe damage to the new weirs (Fig. 6), and today there are none on Stoney Creek, and only two intact on the upper part of Eaglehawk. A concrete block structure protects the Glengarry North Road Bridge, while a low concrete wall across the creek bed just above the main bridge traps some of the sediment arriving from upstream. Current erosion "control" is limited to annual bulldozing by the Latrobe River Improvement Trust designed to remove obstacles from the channel floor, and redirect the current away from the eastern bank where undermining results in the loss of valuable farmland. The enlarged waterway beneath the bridges and periodic straightening of the channel through the sediment splays has resulted in progressive downstream migration of the toe of the "delta" or sand splay area. If the process continues coarse sediment may eventually be delivered onto the flood plain of the Latrobe River or even, like the silt, into the Latrobe River itself.

CAUSES OF INSTABILITY AT EAGLEHAWK AND STONEY CREEKS

The historical and field evidence so far reviewed indicates that erosion began along Eaglehawk Creek about the turn of the century, with a phase of rapid deepening lasting until about 1940 since when channel widening has been dominant except in peak flood years such as 1952, 1971 and 1978, when a new channel has been incised into the pre-existing creek floor. Incision of Stoney Creek started in the early 1930s, but like Eaglehawk Creek it is now tending to widen, rather than deepen its channel.

It is unlikely that precipitation in the area has changed sufficiently to trigger channel instability. Local rainfall recording began in the 1880s (Rainfall figures analysed include Toongabbie (daily and monthly) 1889-1920, 1929-1930; Morwell (monthly) 1888-1891, 1899-1915, 1934-80; Traralgon (monthly) 1903-1962.) and analysis of five year running means shows no significant increase since then. Retention of a forest cover over the upper part of the catchments makes it unlikely that the flow regime within the creek has changed greatly, though logging may have had a temporary effect on the magnitude of flood peaks. Bank erosion is widespread along the Latrobe River, but has not been transmitted up Eaglehawk Creek. Two weirs on the lower end of the Creek stop any headward migration of instability and serve as partial silt traps.

Early maps show that the fans once carried open forest vegetation interspersed with denser areas described as "scrub" or "fern" most of which had been cleared by 1935. The impact of this clearing on river flow is unlikely to have been great; the fans occupy only a small and relatively dry part of the catchment and peak flows in the streams, both of which are prone to flash flooding, coincide with periods of heavy rain in the upper catchment associated with prolonged spells of easterly weather and the development of cut off low pressure cells. While it is clear that flash floods may form the main erosive force, the climatic events which lead to flash flooding are not a post-settlement phenomenon, and the fact that the floods have become such an effective agent of erosion must be due to other change.

Destruction of bank vegetation is one contributory factor. In the past many local farmers considerd scrub growth along creeks was undesirable because it limited access by stock and harboured vermin, but today its role in bank stabilisation is acknowledged. Trees are only removed where they have been undermined and are liable to fall into the river, because when this happens they are expensive to remove and there is a risk that they will promote channel widening by diverting the water flow against the bank. In many places today the sides of Eaglehawk and Stoney Creeks are unvegetated because they are too steep for plants to become established, but the absence of any severe flood in the last three years has enabled a number of riparian species to colonise higher sections of the channel floor. While they persist these will assist bed stabilisation, but if they are damaged either by flooding or bulldozing there is a risk that increased sediment mobilisation will follow.

The excavation of a continuous channel through the swamp which once formed a local base level for the upper part of Eaglehawk Creek has also caused erosion. Water now flows to a new base level at the Latrobe River. Figure 7 shows evolution of the new long profile in diagrammatic form. This erosion began in the upper part of the natural channel across the terrace as the relatively steep gradients of the head of a water course became adjusted to the lower gradients of a middle reach. The deepening was then transmitted upstream through headward migration of knickpoints. The channel is deepest where it passes through higher parts of the undulating surface of the fan. This adjustment of long profile is complicated by the redeposition of eroded material as regional gradients diminish from fan to terrace. The redeposition creates a new and steeper gradient at the lower end of the sand splays. As deepening upstream diminishes and the rate of arrival of new sediment declines, the channel starts to erode back through this oversteepened sector creating a new, lower, sand splay as this material in turn is redeposited downstream. Erosion of the channel back up into the fan is comparable to the sequence described by Schumm and Hadley in Wyoming and New Mexico (1957): trenching appears to be initiated at the toe of fan once surface gradients exceed a threshold value, which in the case of Eaglehawk Creek lies at about 0.012. Below the lowest splay the water emerges minus its coarser sediment load, and possessed of superfluous energy. Several authors,

Fig. 6—Wood and concrete drop structure across Eaglehawk Creek outflanked by bank erosion. Looking upstream.

including Komura and Simmins (1967) and Gregory and Park (1974) have shown that this leads to local channel degradation, and this is evident in Eaglehawk Creek. Basalt boulders have been dumped at the head of the channel below the splays in an attempt to prevent the development of deep water holes in the channel floor, eroded by clear water emerging from the depositional zone.

Stoney Creek underwent changes in long profile similar to those of Eaglehawk Creek. It, too, once flowed into a swamp which provided a local base level, but when it was diverted into Eaglehawk Creek in 1933 it adjusted to the changes within the main stream. A photograph taken in 1935 shows the confluence at a stage when they were still at different levels, with the mouth of Stoney Creek about a metre above the channel of Eaglehawk. This disjunction was the origin of a knickpoint which was rapidly transmitted upstream. Stoney Creek began to deepen later than Eaglehawk Creek, and the cross profile (Fig. 4) together with the comparative lack of channel floor vegetation suggests that the transition from a dominance of deepening to one of widening occurred more recently. Much of the recent sediment deposited in the splays downstream probably originated form Stoney Creek rather than Eaglehawk Creek.

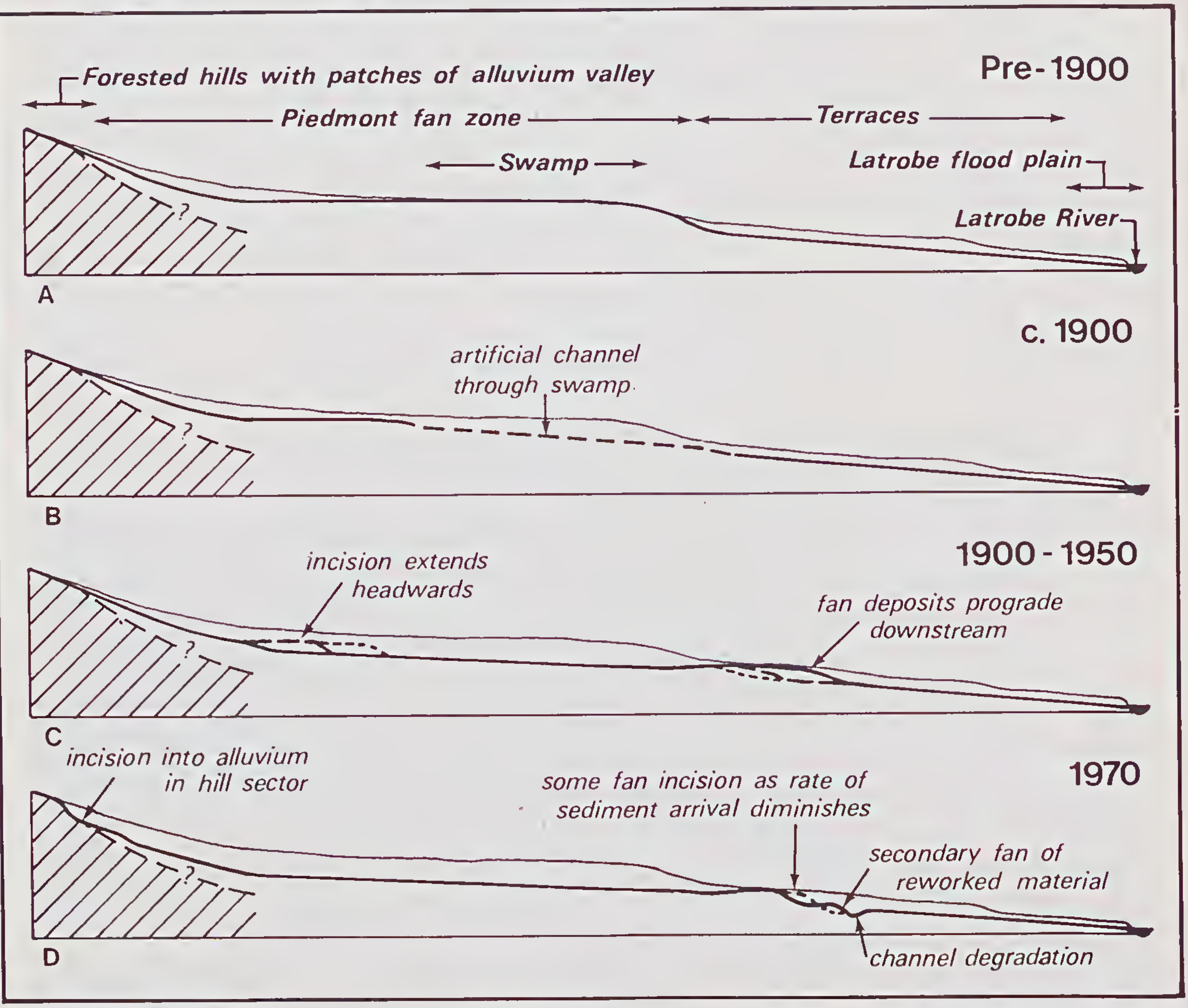

Fig. 7—A, Under natural conditions Eaglehawk Creek had two sectors with a clearly defined channel separated by a swamp which served as base level for the upper channel. B, About 1895 a drain was cut through the swamp, linking the upper and lower channels. C, The steepened reach of the man-made channel through the swamp began to incise back into the upper part of the fan zone. At the same time redeposition of eroded materials built up a new prograding fan across the terrace below the swamp. D, As the incised channel extended back into the hills the rate of erosion slowed, and supply of sediment to the downstream depositional area diminished. The channel at the lower end of the post-settlement fan then began to cut back, creating a secondary sediment splay at the downstream end. Water minus its sand and gravel load emerging from the toe of this secondary splay caused degradation of the channel immediately downstream.

Changes in long profile have not been the only cause of channel instability in Eaglehawk Creek. Although, as stated earlier, there is no evidence for changes in the stream hydrograph due to rainfall trends or catchment modification, interference within the fan zone itself has accentuated variations in run off. One factor in this has been the elimination of the local swamps which formerly served as natural flood retarding basins. Even more important is the retention of run off within the one main channel. Earlier in this paper the natural pattern of run off was described: as is common in fan terrain, watercourses were subject to frequent lateral shifts, so that when flood waters overtopped one channel they created a new one off to the side. When measures were taken to prevent this all the flood flows were retained within the one alignment. The dam built in 1894 to block the overflow into Four Mile Creek ensured that an increased proportion of the floodwater was retained within Eaglehawk Creek; a corollary of this is that flood peaks in Four Mile Creek have diminished and this is one of the few streams in the area today which shows no signs of incision, but rather of having an over-fit channel. A further major increment to the flow of Eaglehawk Creek occurred with the diversion into it of Stoney Creek, effectively increasing the catchment of the middle reaches from 39 km² to 53km². This diversion did not affect lower Eaglehawk Creek, because, as the map (Fig. 1) shows, it already carried the Stoney Creek flow under natural conditions.

Eaglehawk Creek between the railway bridge and the Stoney Creek confluence is therefore receiving the runoff from an additional 14 km² of catchment, as well as containing the flood peaks which formerly passed out of the channel. There is no evidence from which to estimate the magnitude of the flood formerly required to overtop the banks and flow into alternative channels, but it is known to have occurred several times each year. This implies that even moderate floods with a return period of less than a year used to be dispersed, but were thereafter retained within the main creek, and as Dury (1977) has suggested, these are particularly important in determining channel capacity.

CONCLUSION

In suggesting that river channels in Victoria were stable over the few hundred years prior to European settlement it is necessary to clarify the definition of stability. Course changes took place, and fan construction was actively occurring in many areas. A corollary of this is that the rivers were carrying sediment, so that catchment erosion must have been quite widespread. The post-settlement onset of vertical instability has often been initiated through attempts to control pre-settlement lateral instability. Channelling and swamp drainage have created stream-bed gradients considerably steeper than those occurring naturally and the response of many rivers has been to incise their former channel floors.

The rate of incision diminishes as streams again approach a stable grade, or when they encounter bedrock. Minor control structures are rarely effective on channels prone to flash flooding, particularly if they are located in poorly consolidated sediments, and stabilisation can only be achieved with massive dams, the cost of construction of which usually far outweighs the benefits obtained. Many problems result from the less visible end of the process, the redeposition of eroded material, which masks farmland, devalues creek water supplies, obliterates fence lines, and threatens road and rail links. The insertion of small sediment traps along the channel may help by retaining some of the sediment within the creek bed at the cost of transforming surface into subsurface flow.

Eaglehawk and Stoney Creeks have passed through the phase of maximum instability as they adjusted to human modification, but their present near-stable condition is a precarious one. Another severe flood is likely to wash out the two remaining intact drop structures which together hold a head of just over a metre, and initiate a knickpoint which, as it migrates headwards, will threaten the causeway crossing at Frasers Road. A flood of this magnitude could be caused by a recurrence of the meteorological conditions experienced in 1952, or by a less rare climatic event exacerbated by human interference in the catchment such as renewed logging or a re-opening and enlargement of the old quarry just above Frasers Road. The answer to the difficulties posed by eroding channels appears to be to adapt to changes that have occurred rather than attempt to reverse them, but also to guard against any environmental modifications which might result in the initiation of a further phase of marked instability.

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